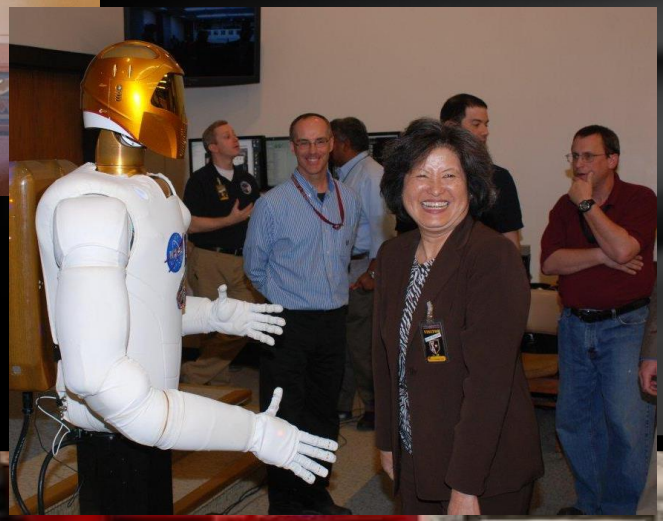
Robotic Handling of High-Consequence Materials: Sellafield, WIPP, Hanford

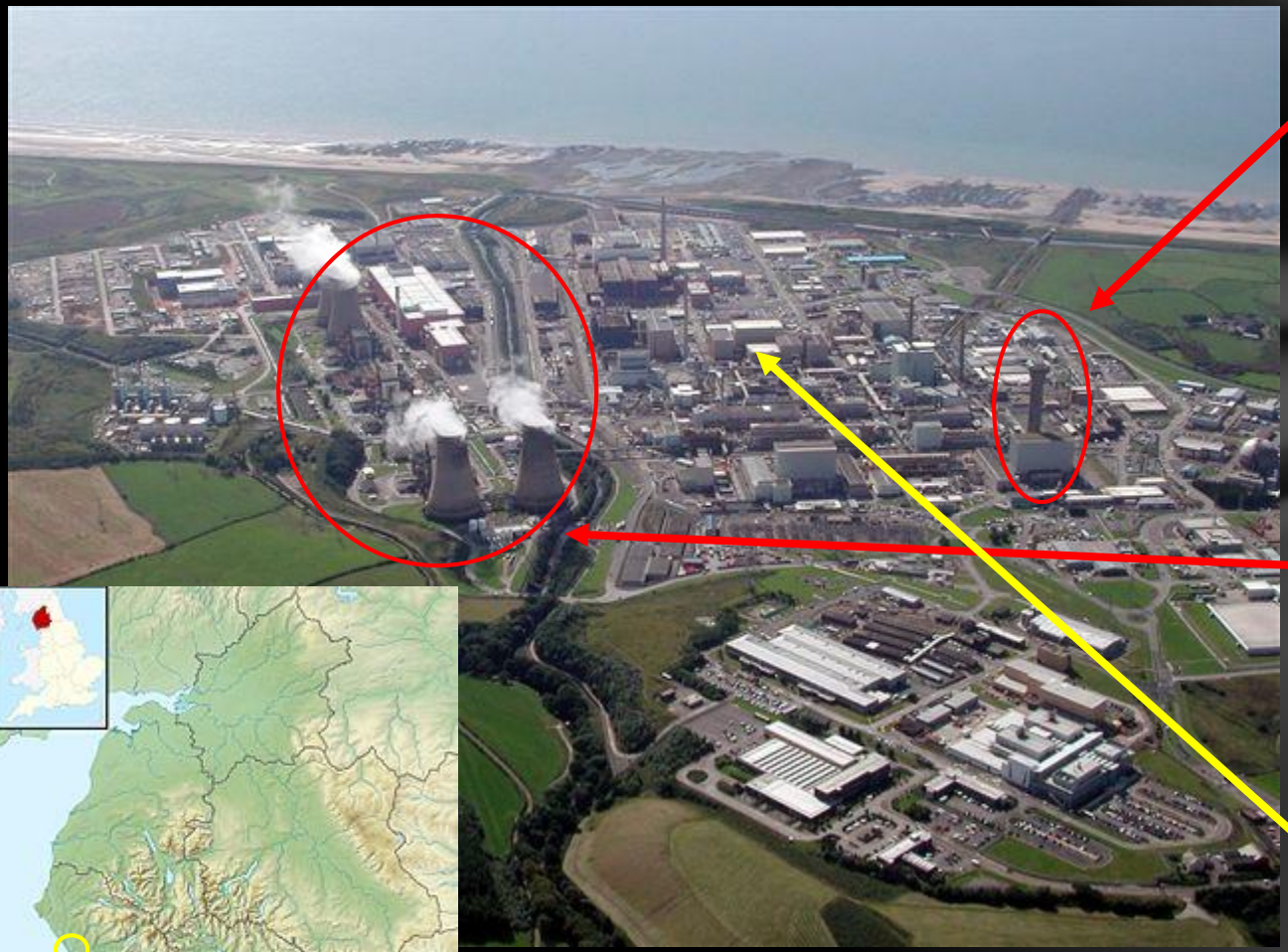
Richard Voyles

Purdue University

USAMRIID and Sellafield trips



Sellafield, UK Visit – April 2015



Windscale Pile

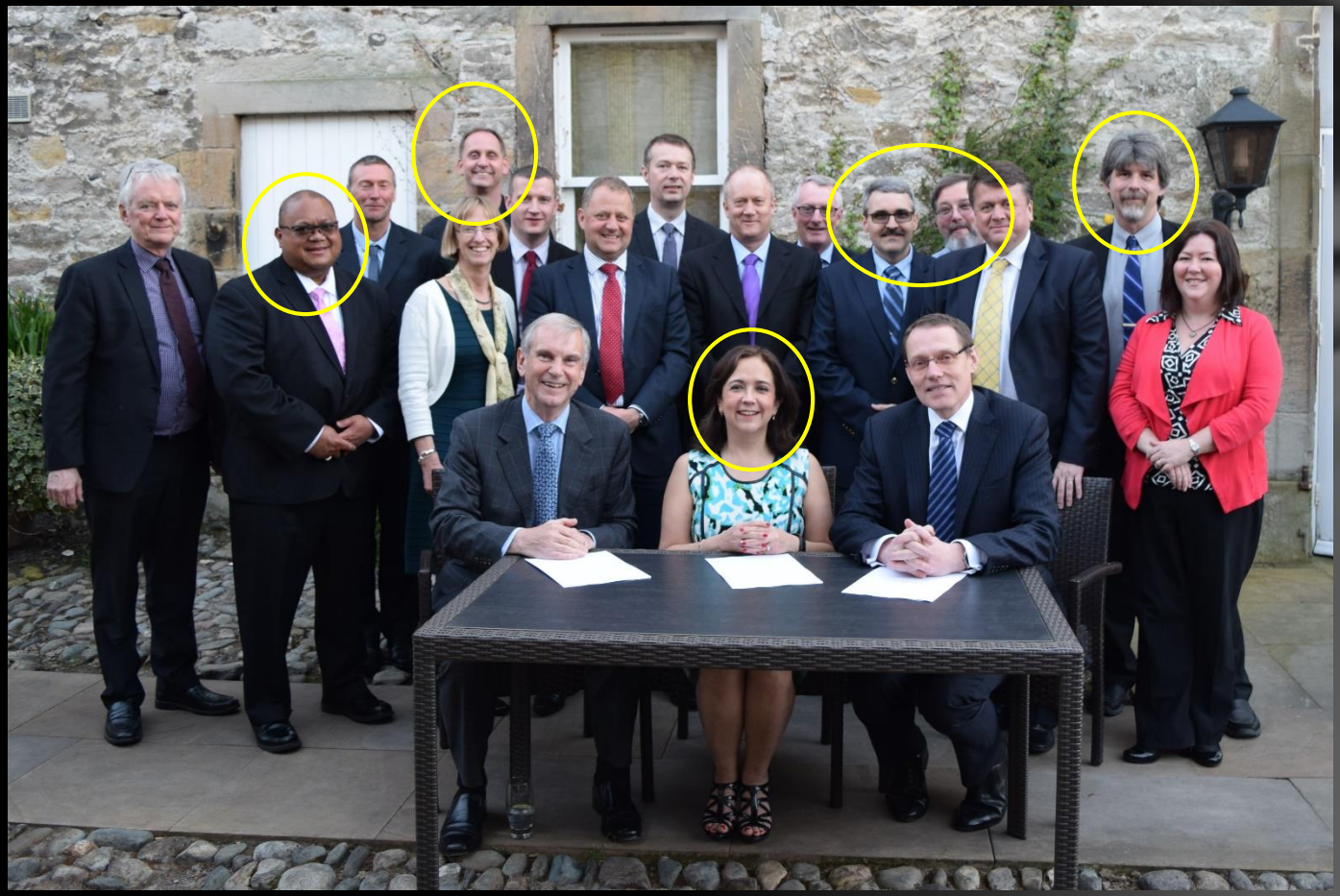
- 1950, aluminum clad uranium
- Spent Fuel Sludge
- Air-cooled

Calder Hall

- World's first industrial-scale
- 1956
- Plutonium

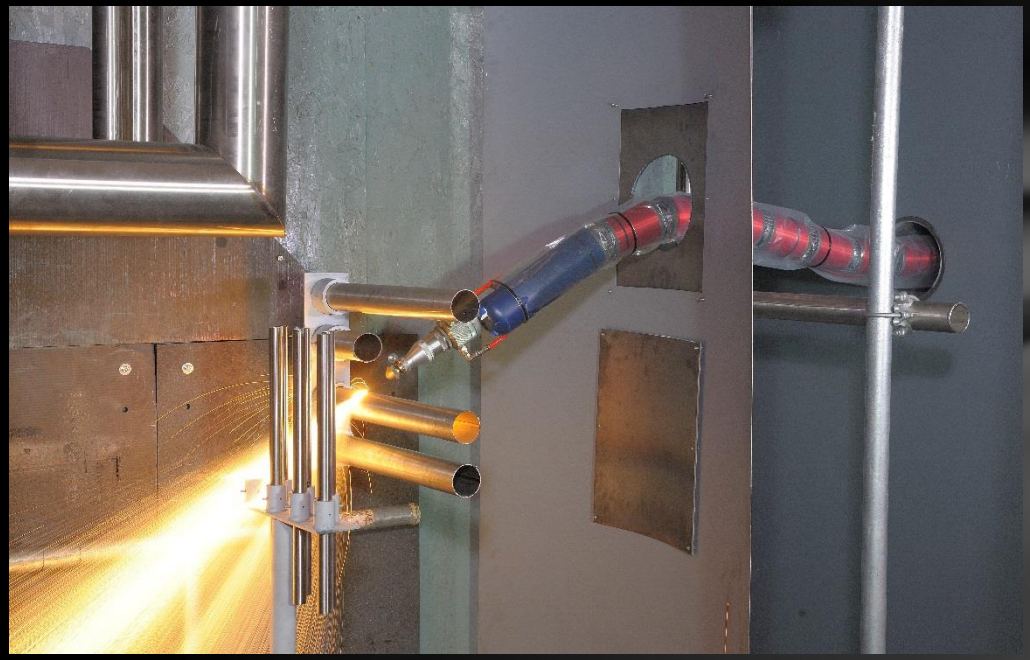
Waste Re-Processing

US Delegation

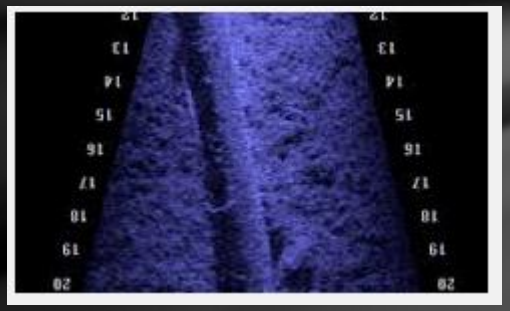


UK Robotic Handling Cell and Simulation

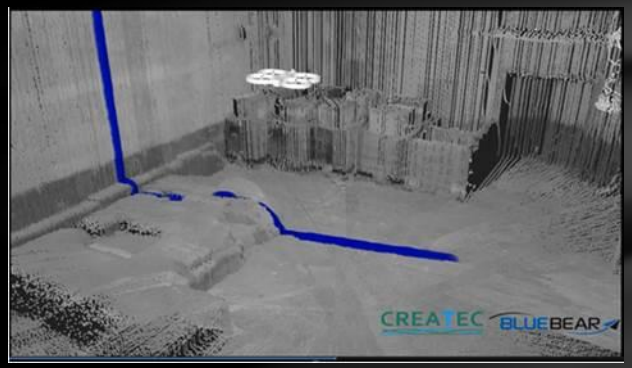
UK LaserSnake



UK ROV Investigation of Spent Fuel Pools

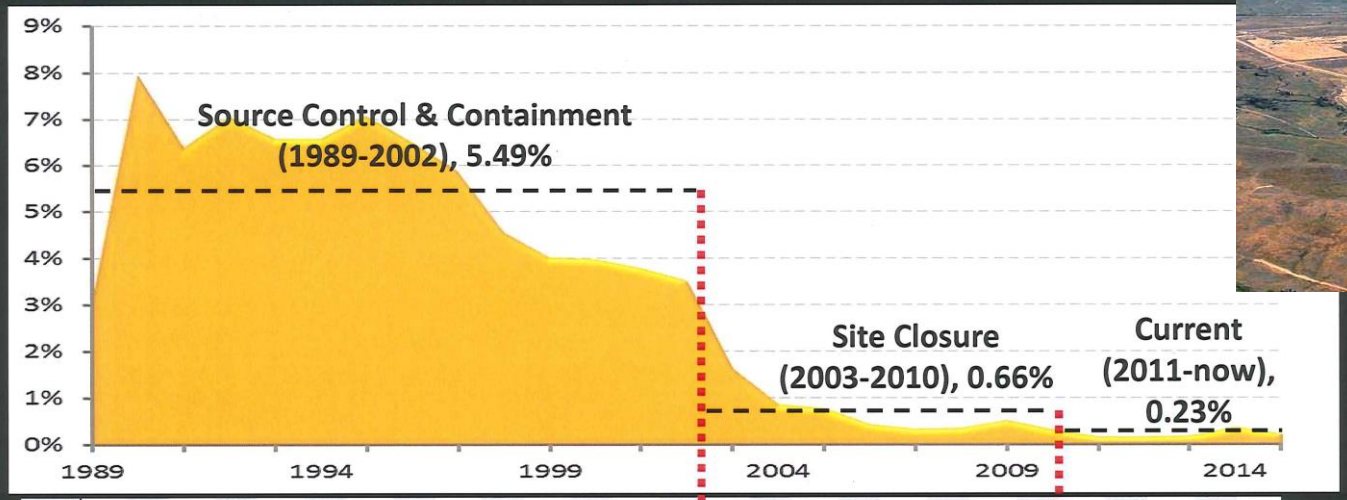


UK UAV SLAM Investigation



DOE Technology Investment

Historical Technology Funding



FY	89	90	91	92	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15
EM ($B)	1.7	2.3	3.6	4.3	5.5	6.0	5.8	6.1	6.0	5.9	5.9	5.9	6.4	6.7	7.0	7.0	7.3	6.6	6.2	5.8	6.0	6.0	5.7	5.7	5.3	5.8	5.9
TD ($M)	52	183	230	303	362	394	410	396	352	269	237	235	242	236	114	61	58	29	21	21	32	20	10	10	10	22	14
%	3.1	8.0	6.4	7.1	6.6	6.6	7.1	6.5	5.9	4.6	4.1	4.0	3.8	3.5	1.6	0.9	0.8	0.4	0.3	0.4	0.5	0.3	0.2	0.2	0.2	0.4	0.3

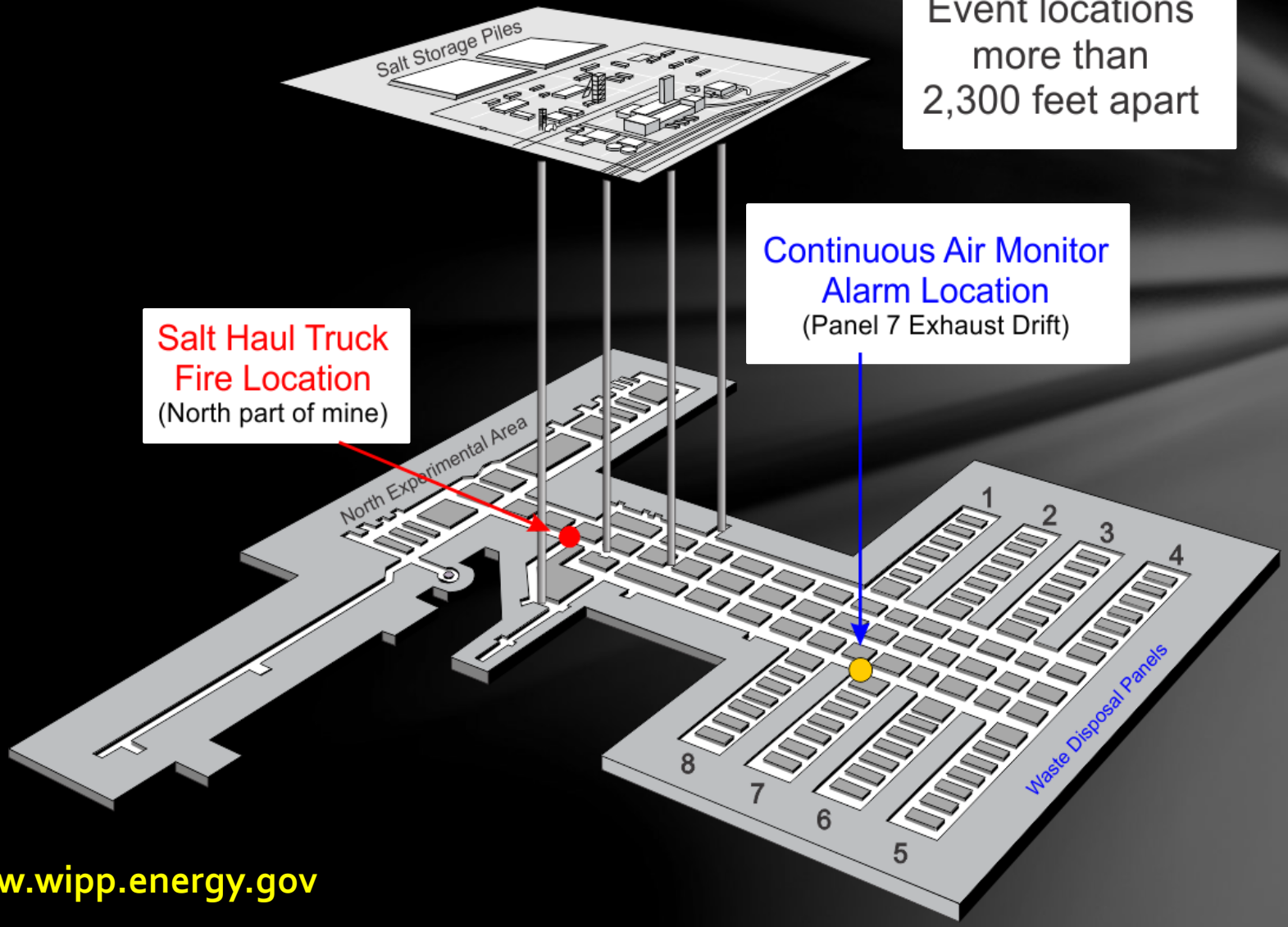
DOE Sites

WIPP, Carlsbad, NM

Savannah River, SC

Hanford, WA

Recap of Incidents: Layout of the Underground



www.wipp.energy.gov

Waste Isolation Pilot Plant – Feb, 2014 Fire

Incidents at WIPP – Radiological Release

February 14 Radiological Release

- AIB Report, Phase I issued April 24, 2014
- AIB Report, Phase II issued April 15, 2015

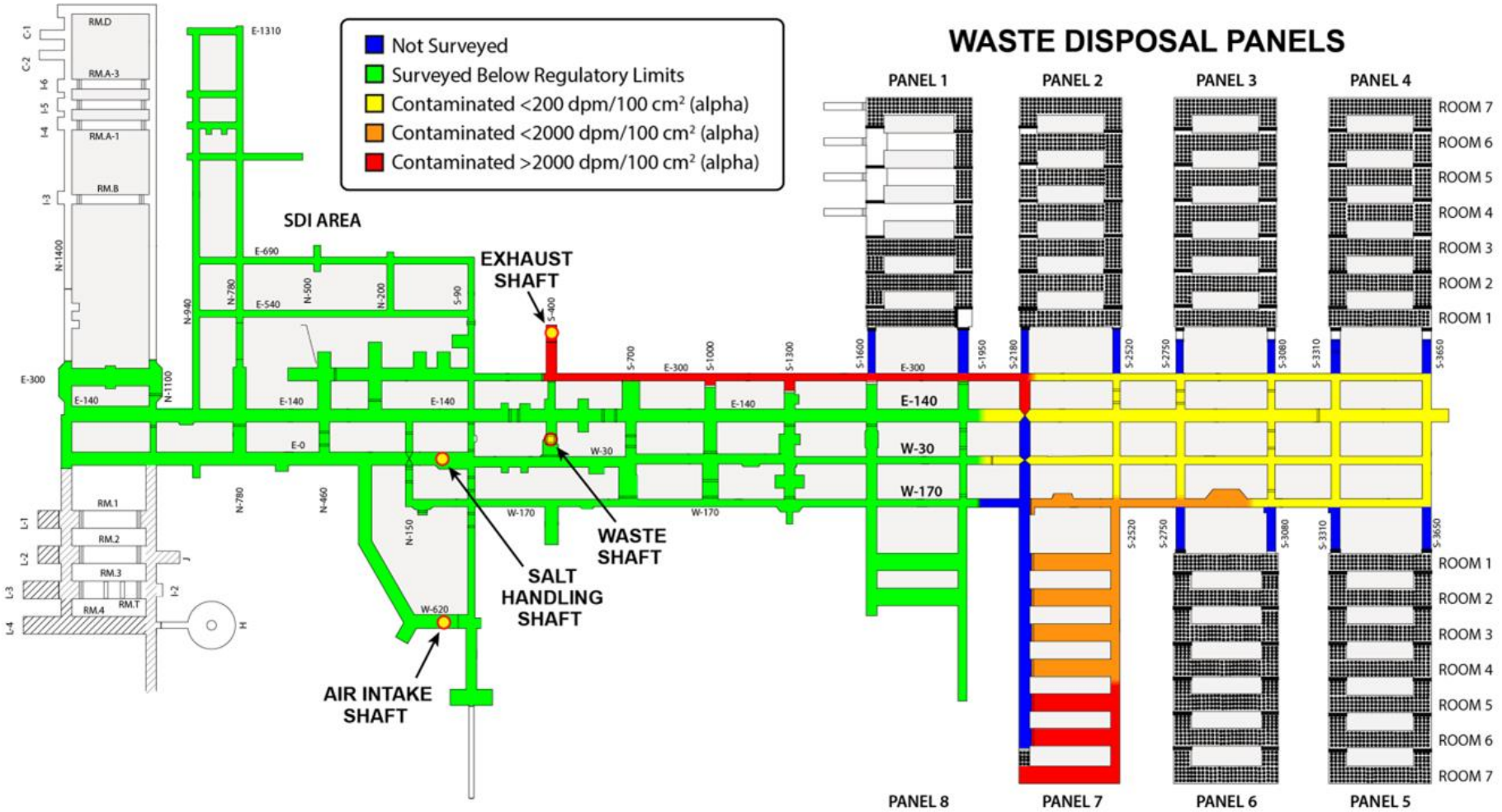
Key Recovery Steps toward Resumption of Operations

Nuclear Safety Document Revisions
Safety Management Program
Revitalization
Underground Restoration
- Re-Establish Degraded Equipment
- Fire Protection
- Maintenance and Ground Control
- Radiological Roll-back
- Soot cleaning of electrical panels

Expedite mine stability
Initial Panel 6, Panel 7, Room 7 Closure
Interim Ventilation
Supplemental Ventilation Modifications

Waste Isolation Pilot Plant

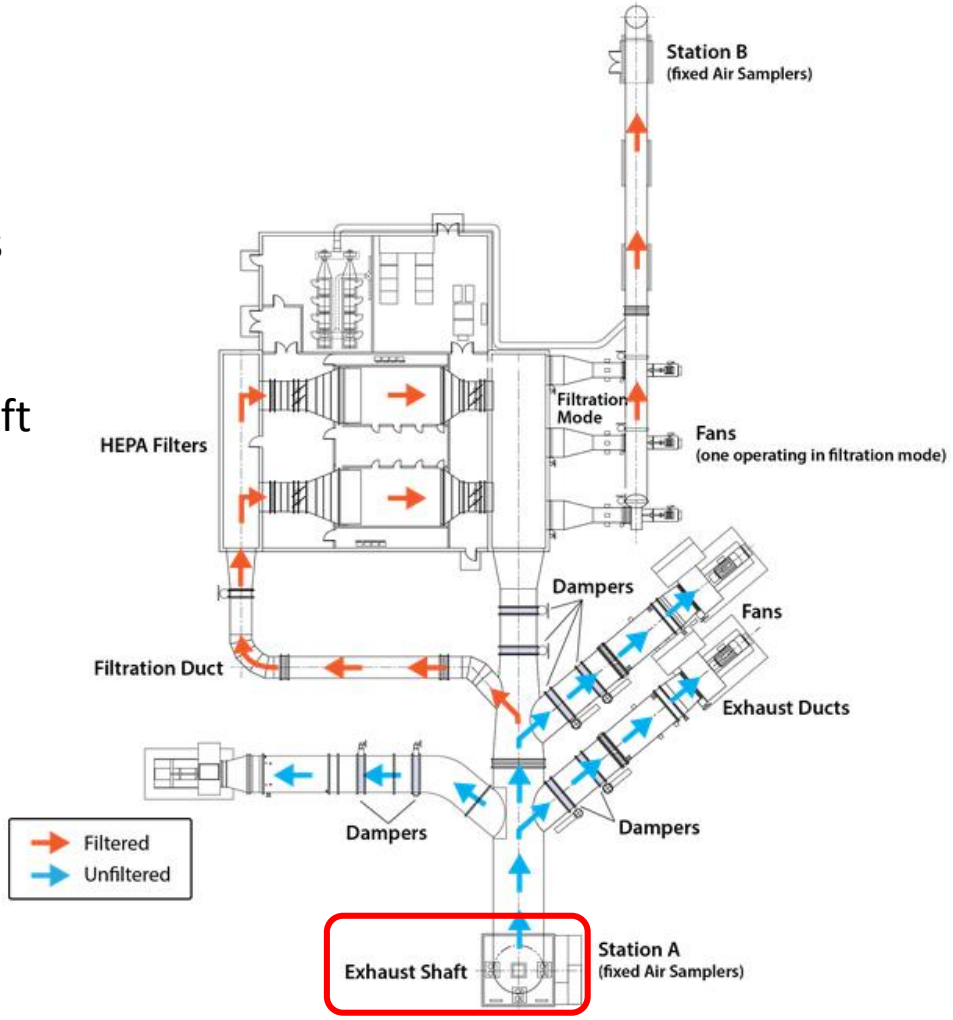
Radiological Rollback



PURDUE UNIVERSITY

WIPP: Ventilation System

- Nearly all of the 200 mg of material has been recovered in the HEPA filters
- Possible trace amounts of americium left in the exhaust shaft
- The shaft is circular in cross section, 14 feet in diameter, and about 2150 feet long, with 60,000 cubic foot air per minute (CFM) flowing through it.



WIPP ventilation system. (reprinted from www.wipp.energy.gov)

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Challenge

Challenges in the inspection and cleaning of the exhaust shaft:

- constrained environment
  - Very high aspect ration (660 m x 4 m)
  - Partially lined column
    - Concrete lined above 900', rough-hewn below
  - Water intrusion
    - 1 – 10 GPM in unlined section
- sensing of americium
  - Low energy (~0.06 MeV)
  - Small quantities
  - Requires physical sampling vs. non-contact

UAV solution of using fully-actuated Dexterous Hexrotor :

- precision flight in close proximity to the structure walls
- ability to maintain contact forces at swabbing sites

Hanford/INL Site Visit

Richard Voyles

Professor and Associate Dean for Research

Purdue Polytechnic Institute

Away Team:

Rob Ambrose

Wendell Chun

Bill Hamel

Blake Hannaford

Rod Rimando

Veronica Santos

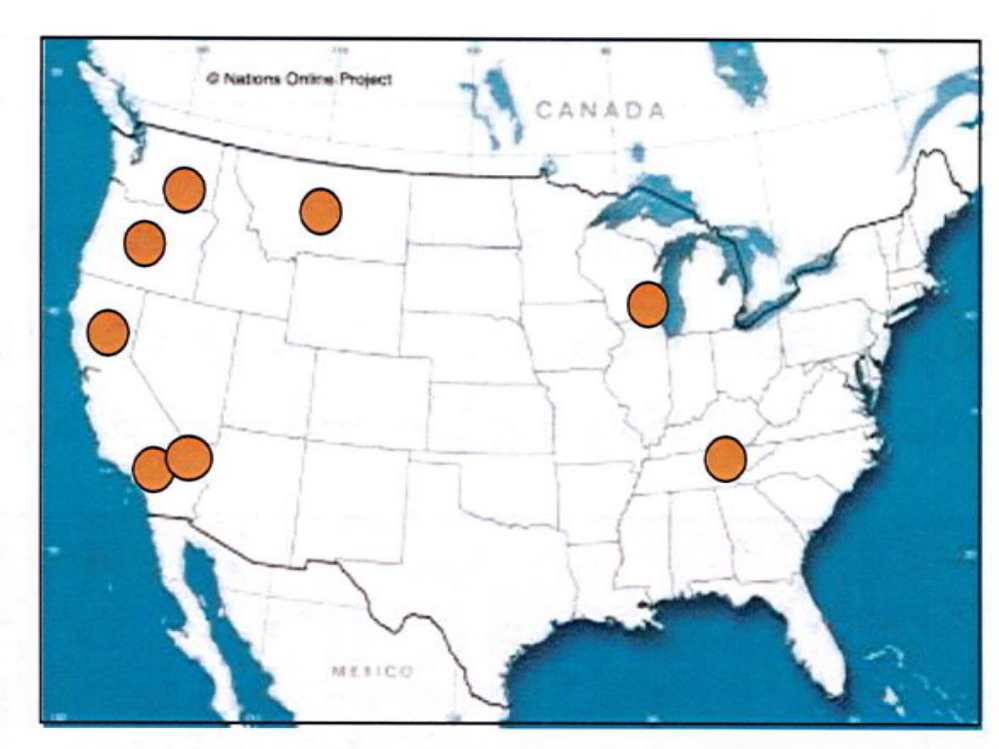
Satoshi Tadokoro

Richard Voyles

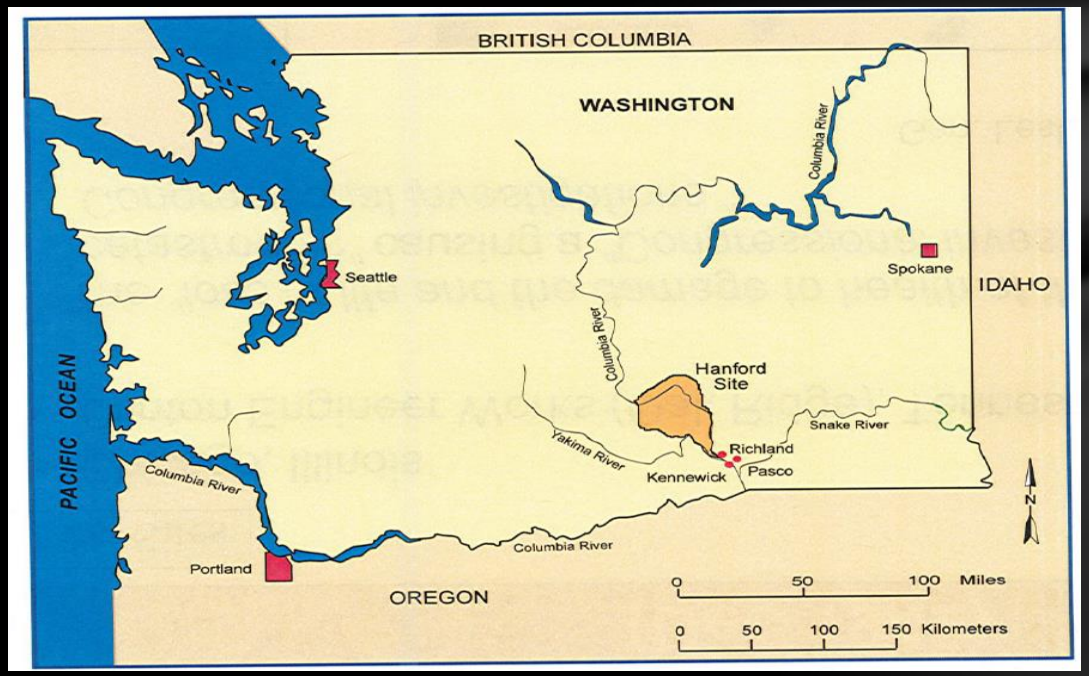
Red Whittaker

Site Selection for Secret Plutonium Plant – December 1942

- Initial Sites:
  - Chicago
  - Oak Ridge
- Secondary Sites:
  - Montana
  - Oregon
  - California
  - Washington



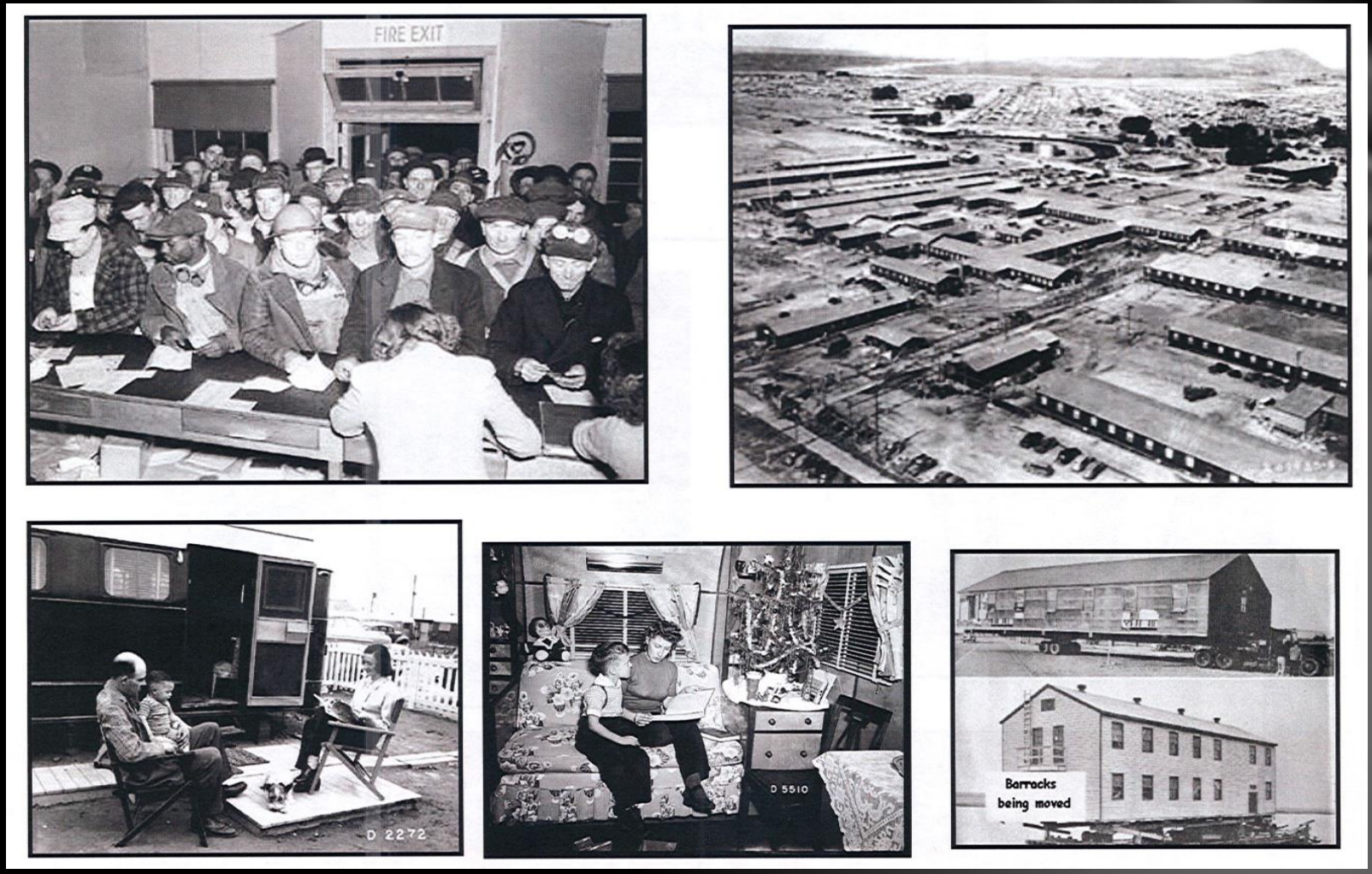
Hanford Selected



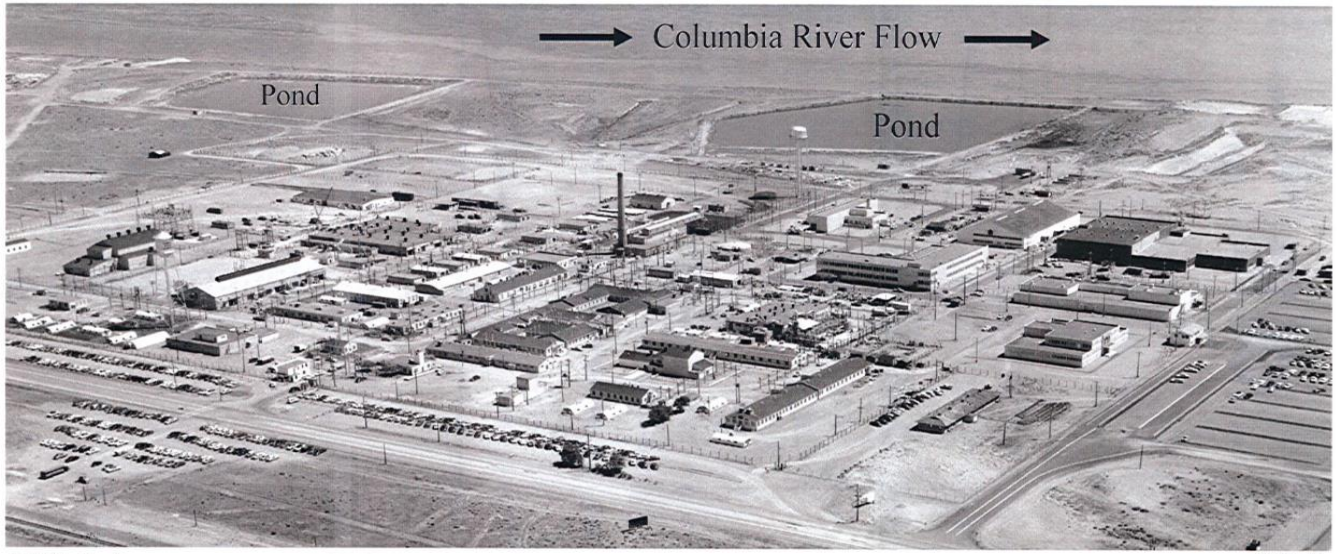
- Letters issued citing 2nd War Powers Act
  - March 1943
  - Leave land
  - 670 sq mi
  - ~1% of WA


HANFORD REACH
WASHINGTON
HANFORD
CENTRAL PLATEAU
Tank Farms
Waste Treatment Plant
200 West Area
200 East Area
HANFORD REACH
300 Area

Camp Hanford, 1943-1946

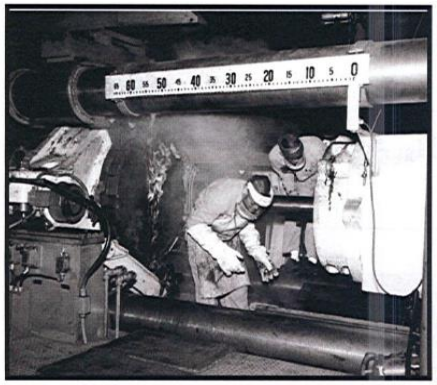


Uranium Fuel Fabrication (300 Area)



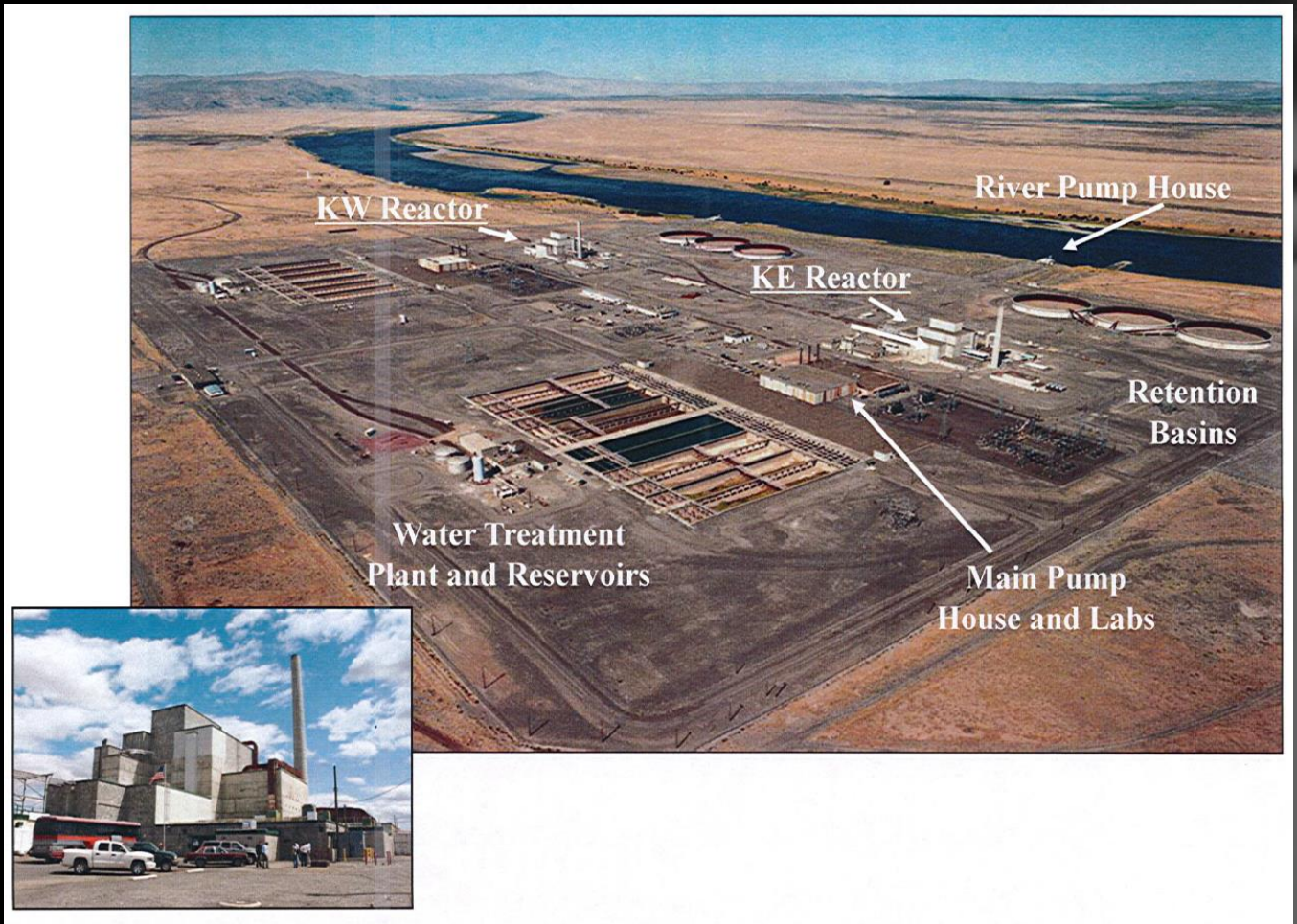
1953 photo

741fb.52
2052

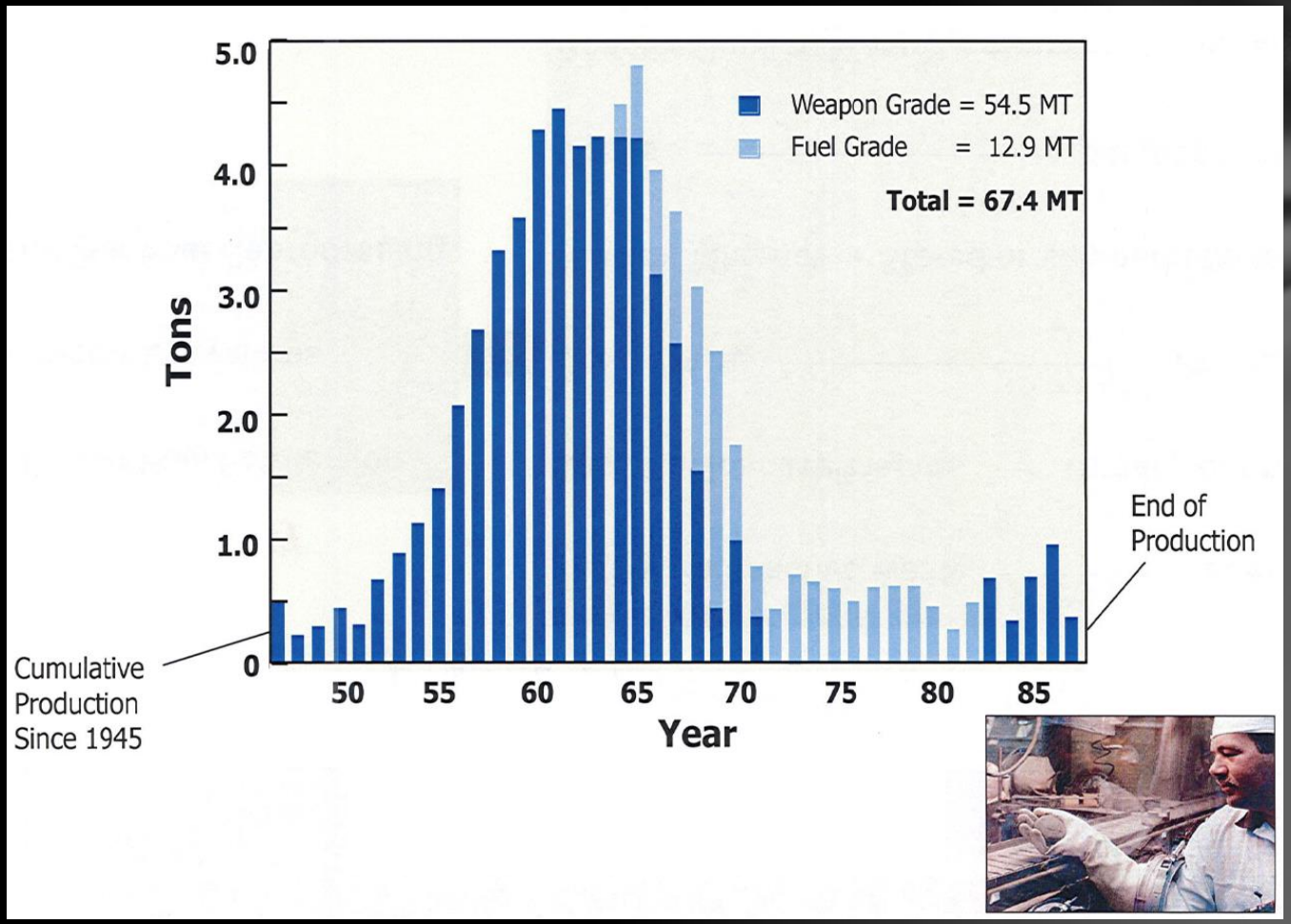


- ~20 million fuel slugs
- 80% unenriched (99.7% U^{238}; 0.3% U^{235})
- 20% slightly enriched (<1.2% U^{235})
- Al or Zr clad fuel

2 of 9 Reactors Along Columbia (100 Area)



Hanford Plutonium Production 1945-1987



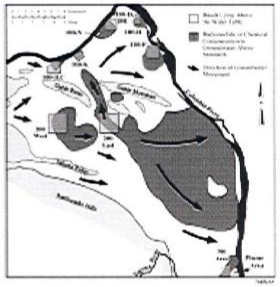
Great Variety of Nuclear Materials

200,000 m^3
195 M Curies

Tank Waste

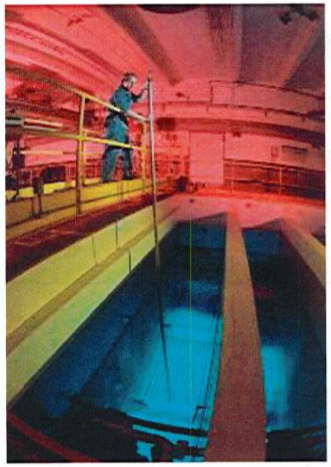
Tank Construction

Facilities



Soil and Groundwater

110 M Curies



Sr and Cs Capsules

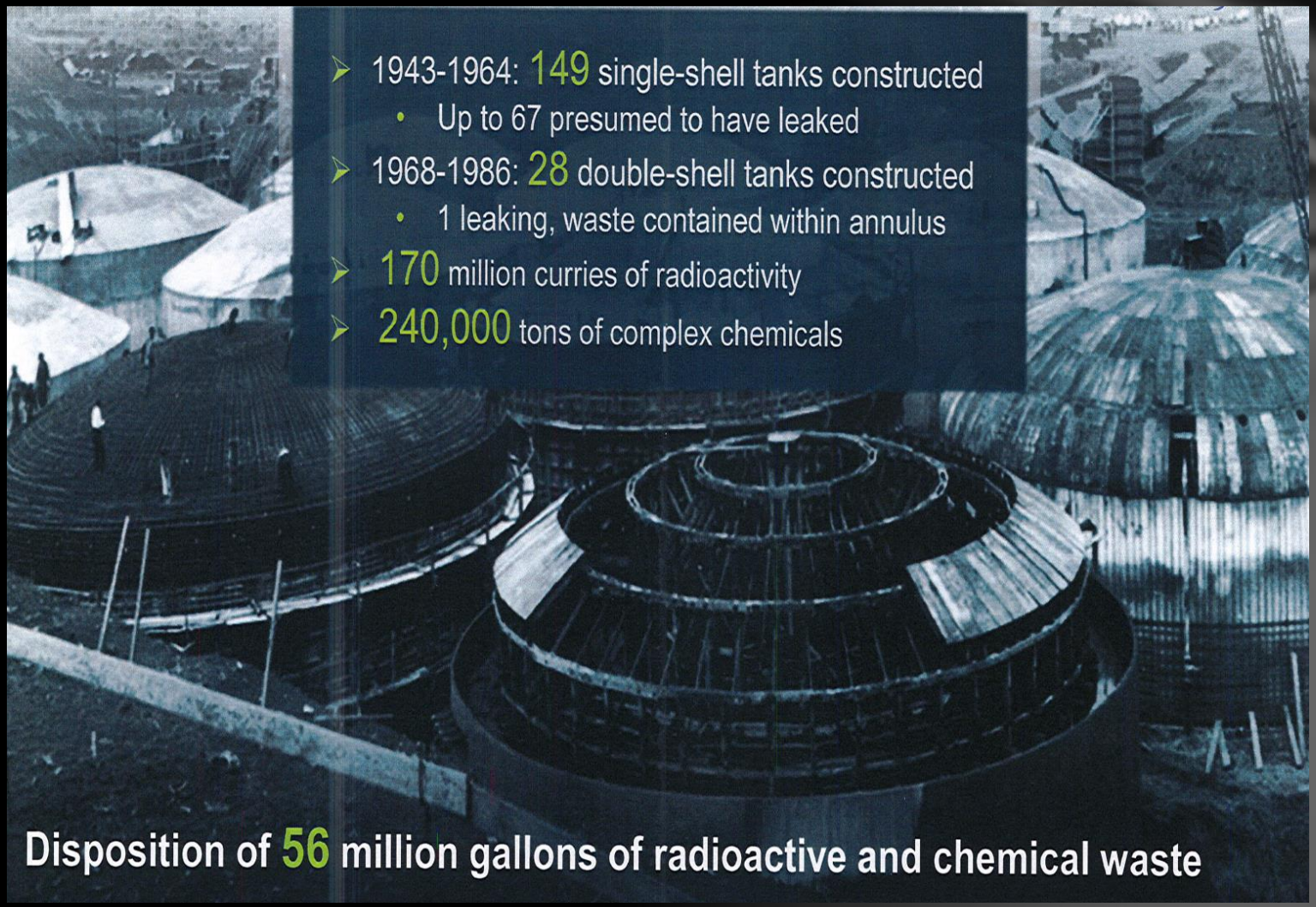
Spent Fuel

Pre-1970 Buried Waste

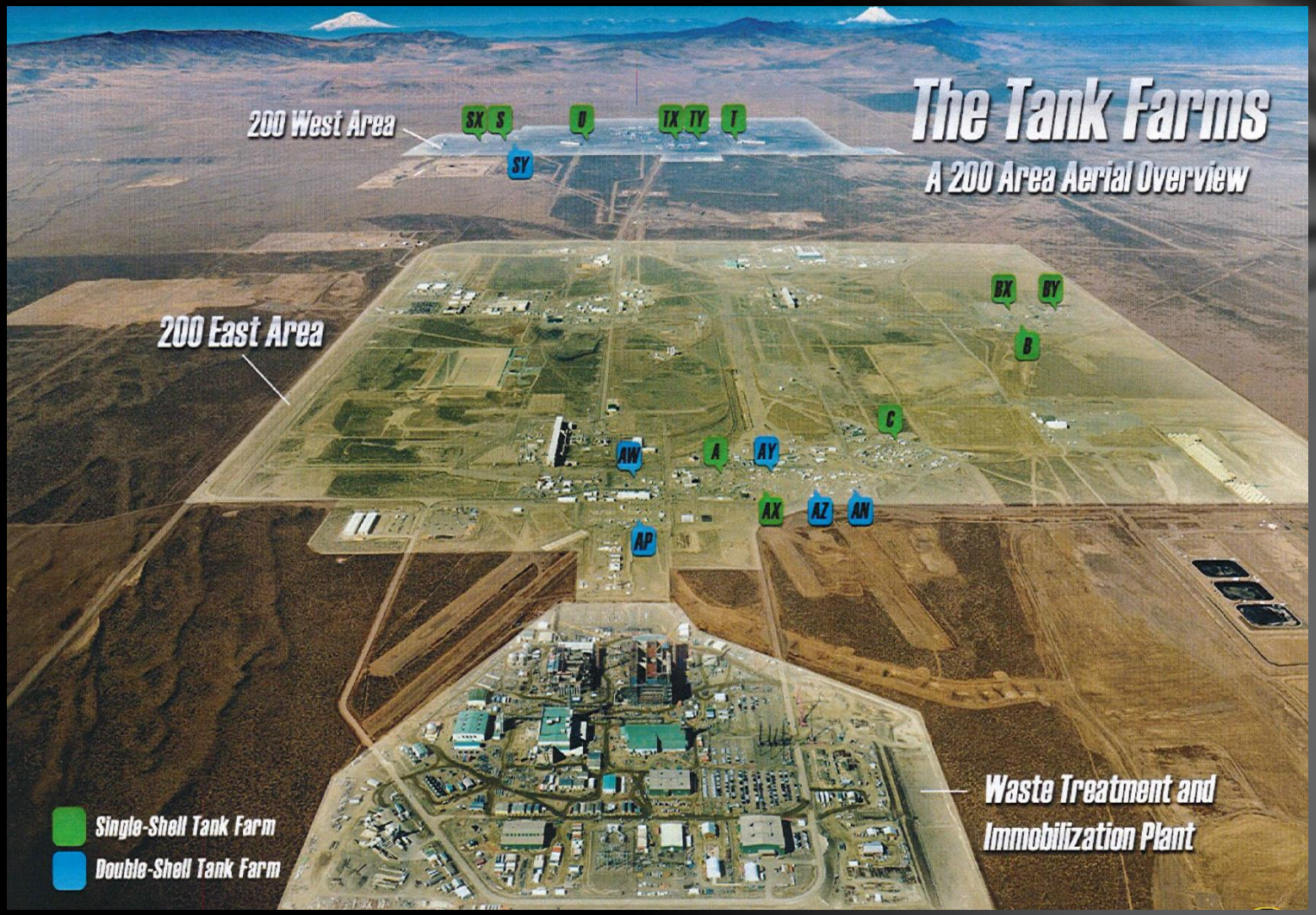
Post-1970 Solid Waste

~ 350 M Curies TOTAL

Tank Farms – Hanford's Biggest Challenge



Tank Farms – Geographic Spread



RETRIEVAL TECHNOLOGIES

Mobile Arm Retrieval System Sluicing (MARS-S)

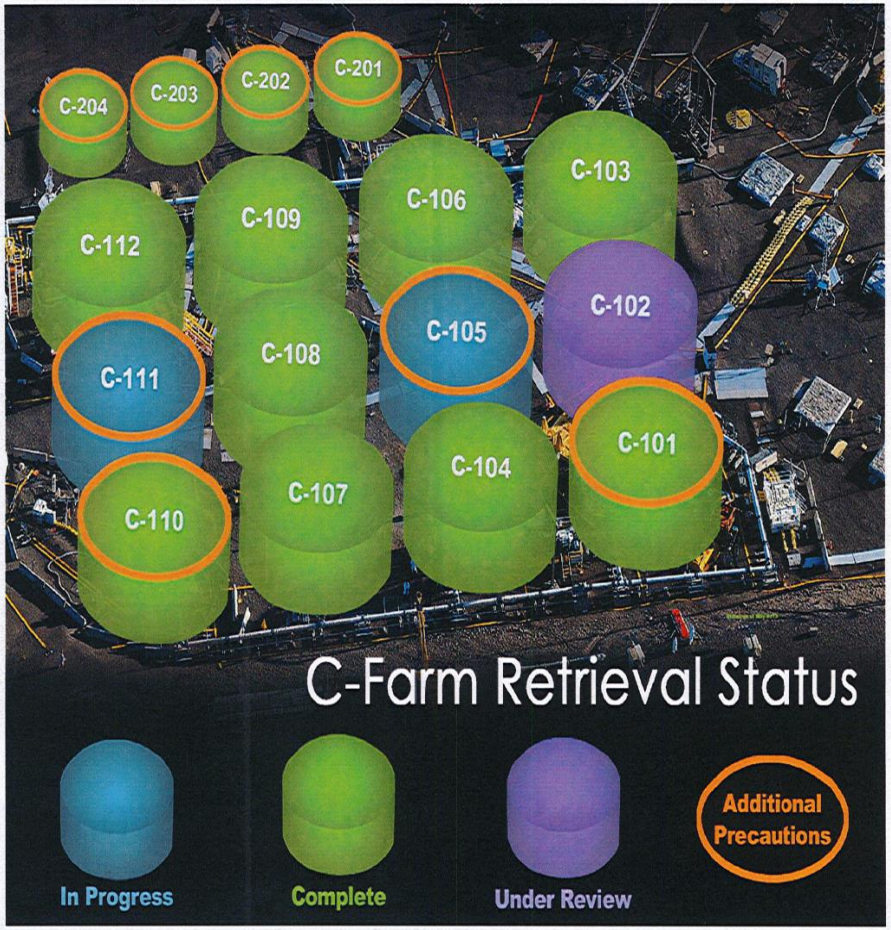
Chemical Dissolution

Enhanced Reach Sluicing System (ERSS)

Modified Sluicing

In-Tank Vehicle (Foldtrack)

Mobile Arm Retrieval System Vacuum (MARS-V)

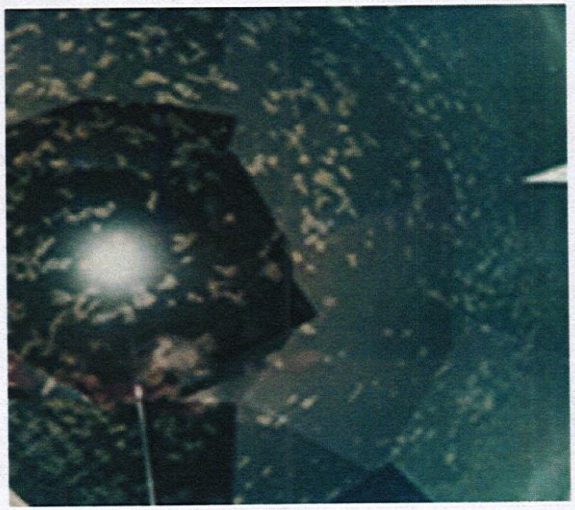


Tank Wastes

Saltcake
23M gallons

Mostly water-soluble salts; small amount of interstitial liquid

Supernate
21M gallons

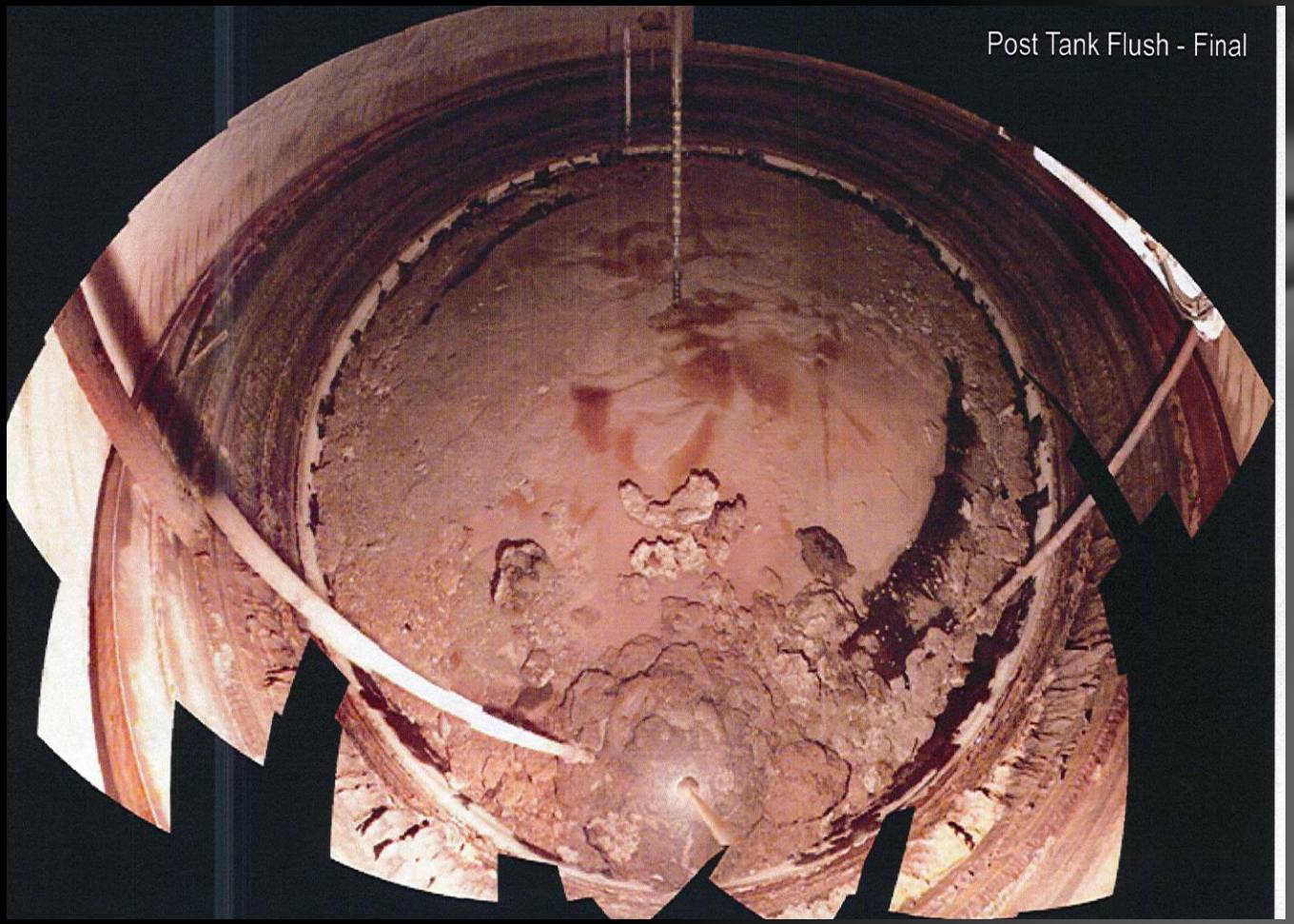


Any non-interstitial liquid in the tanks – similar to saltcake in composition

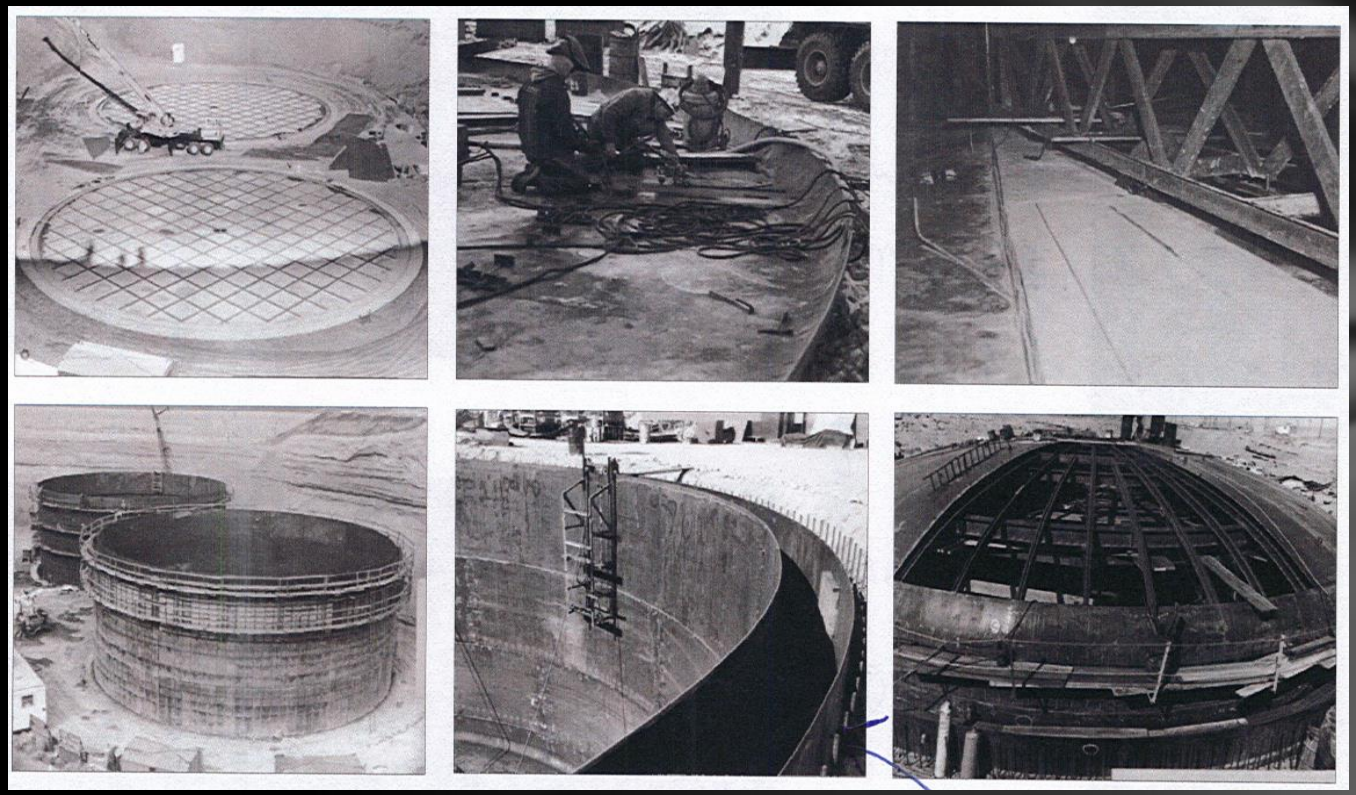
Sludge
12M gallons

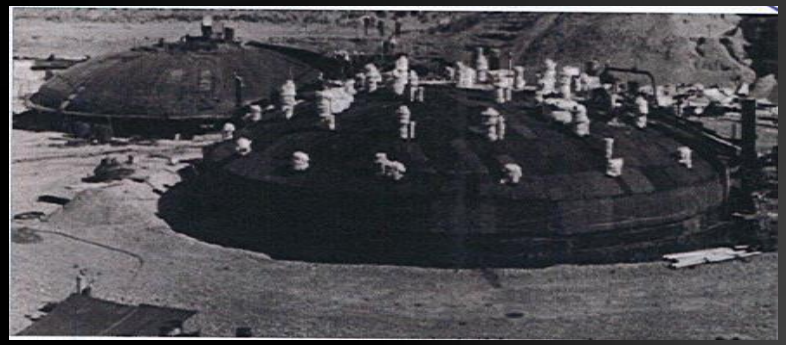
Water-insoluble metal oxides, significant amount of interstitial liquid – texture similar to peanut butter

Tank C-102

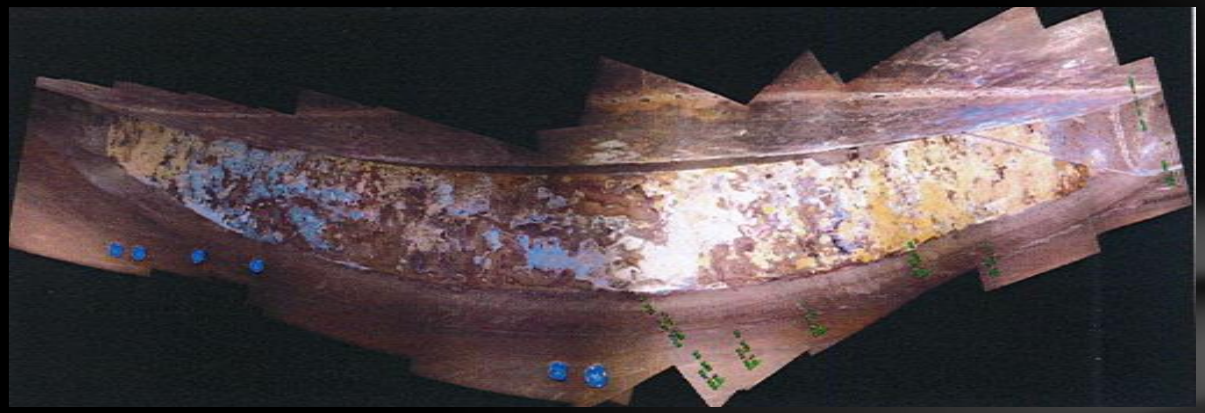


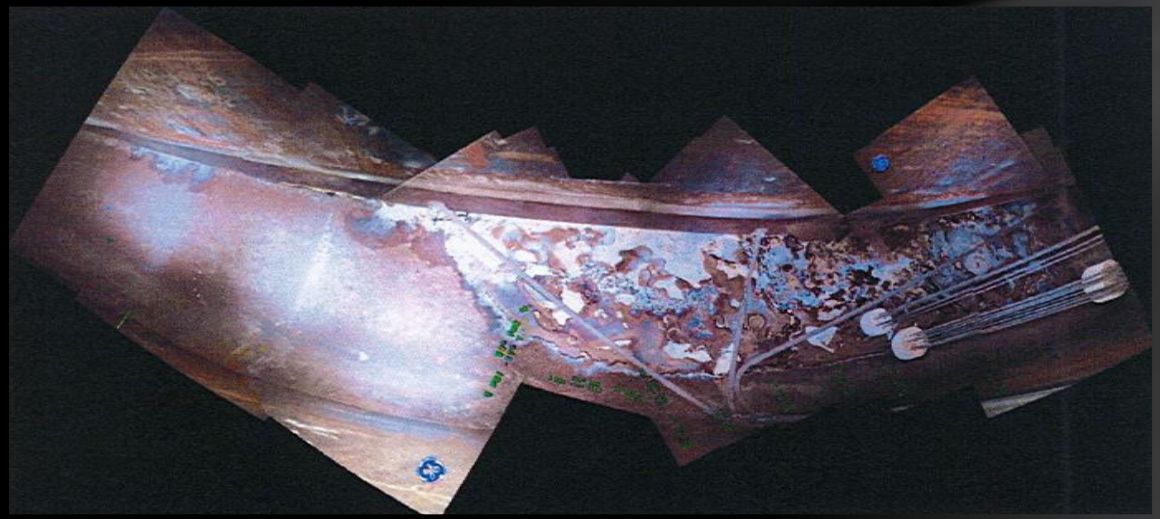
Tank AY-102 Construction (DWT)



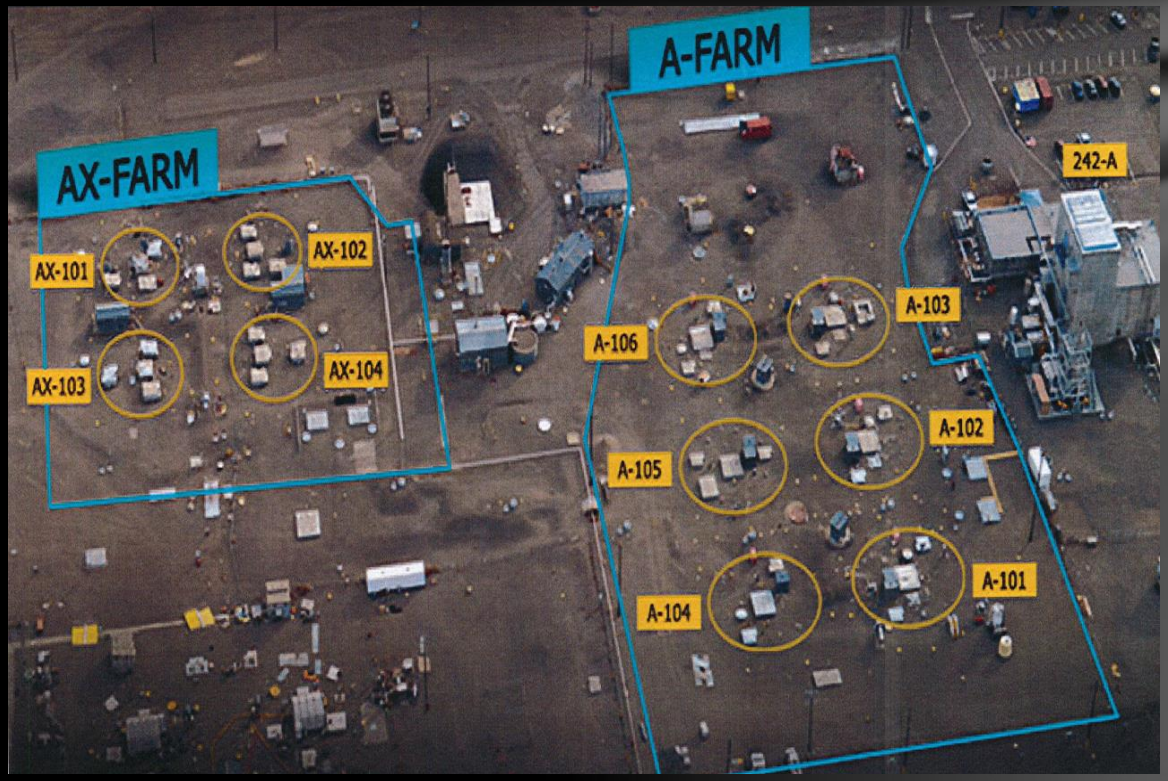


AY-102 Leakage

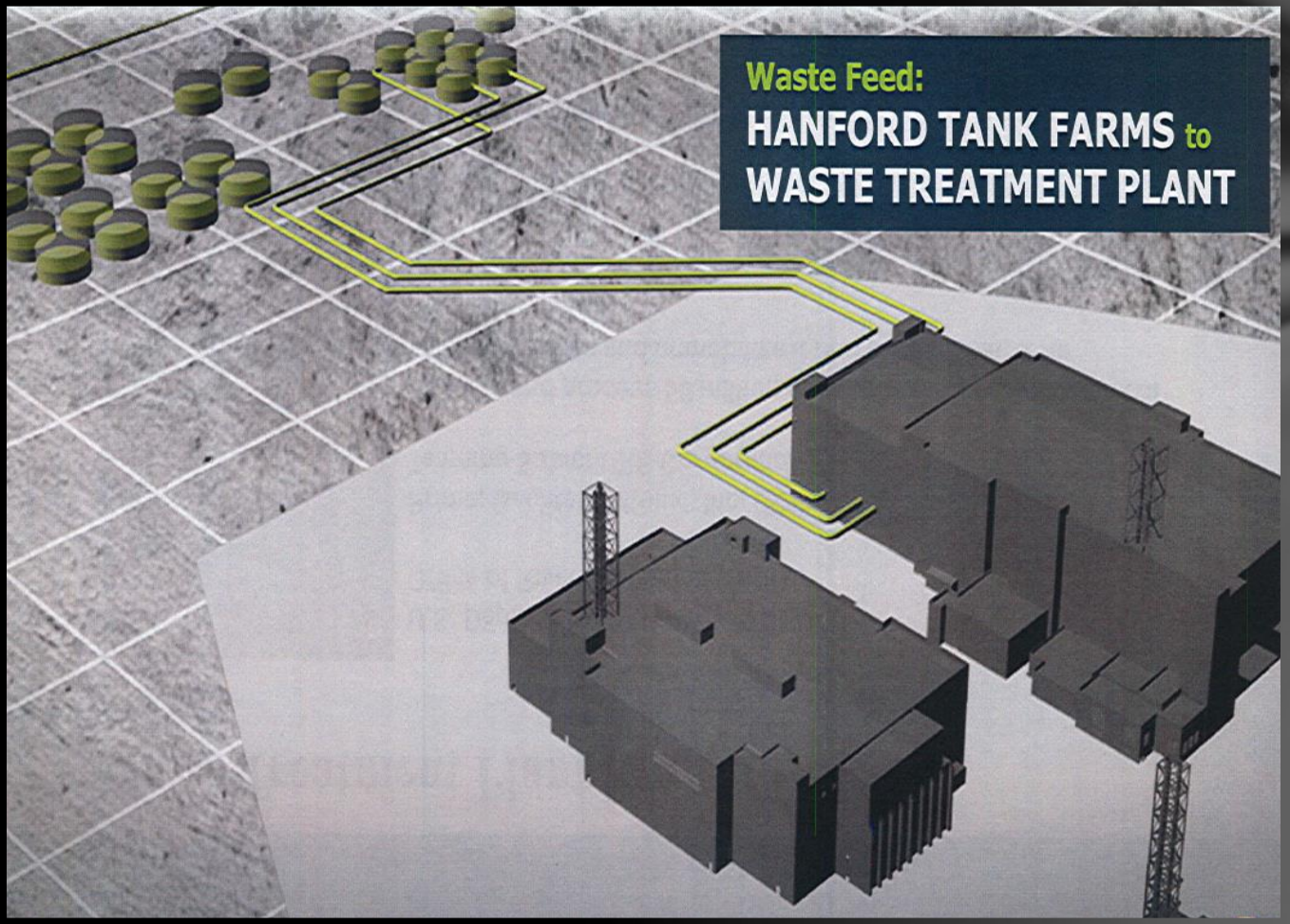




Single-Wall A Farm

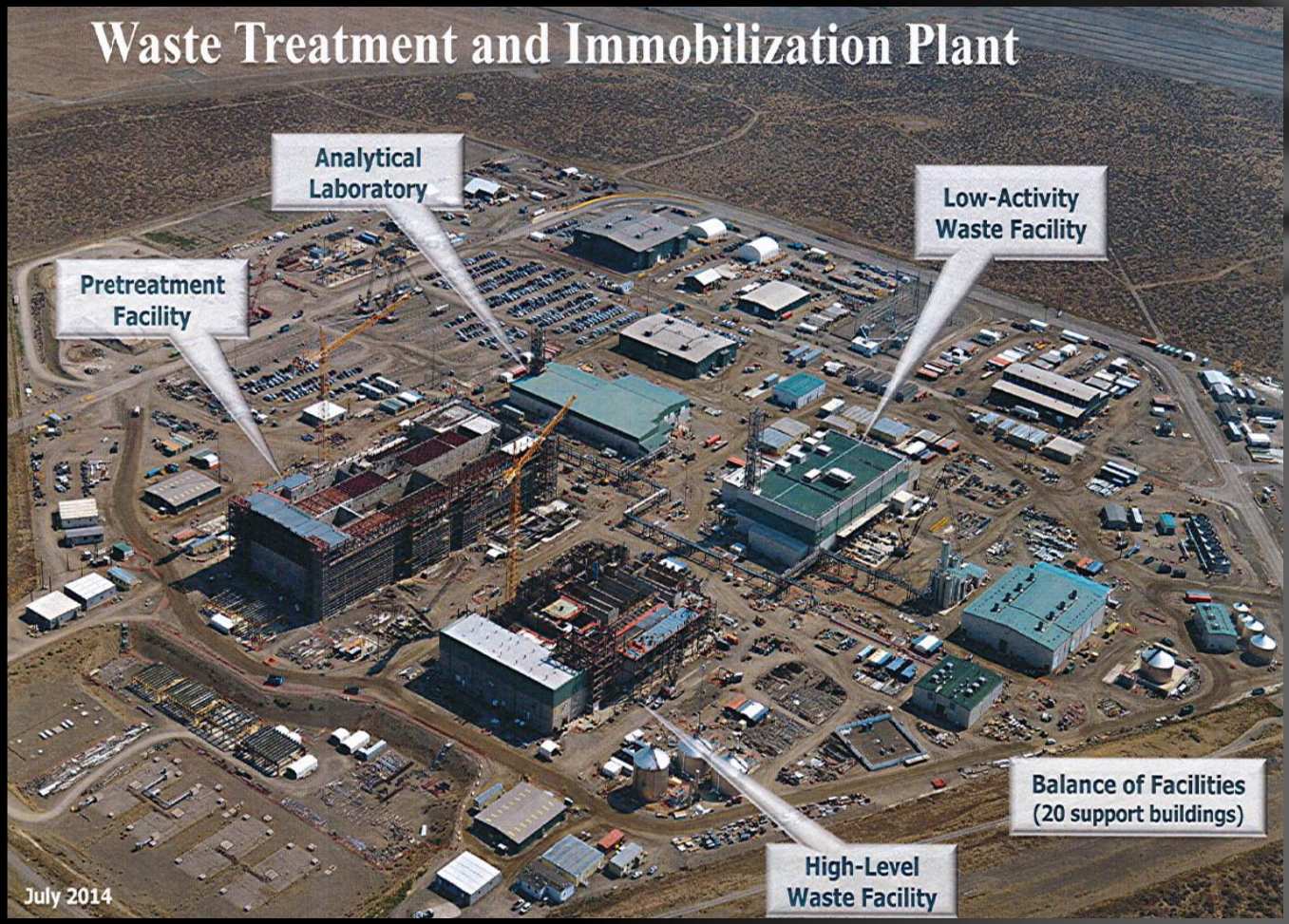


Storage Tank Farms

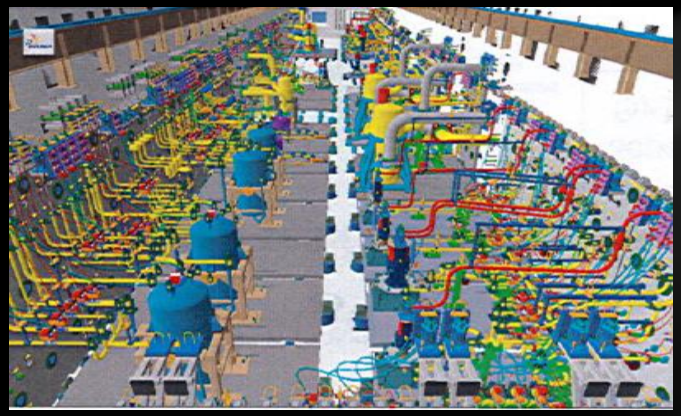


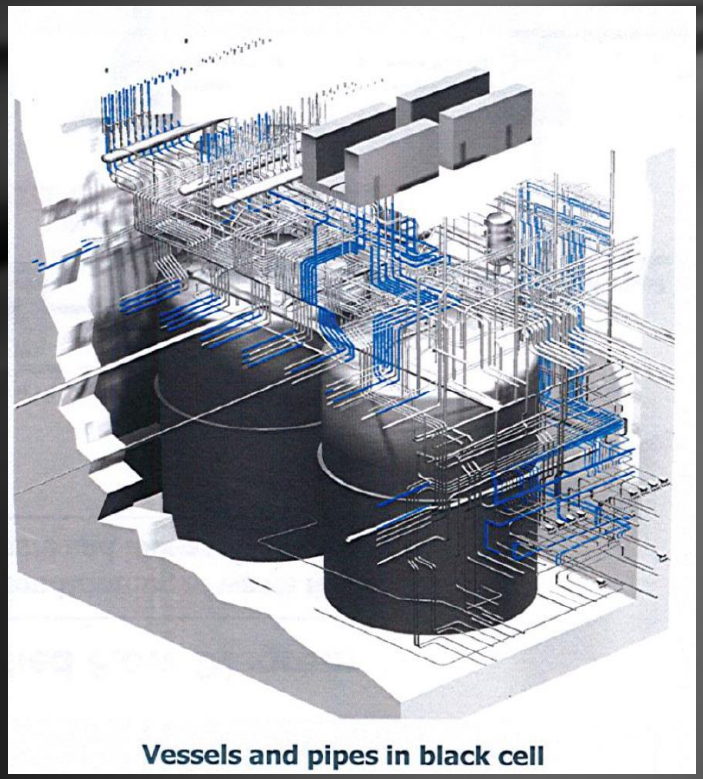
From Tanks to Storage

Waste Treatment Plant (WTP)



Pre-Treatment Facility (separate solids and liquids)



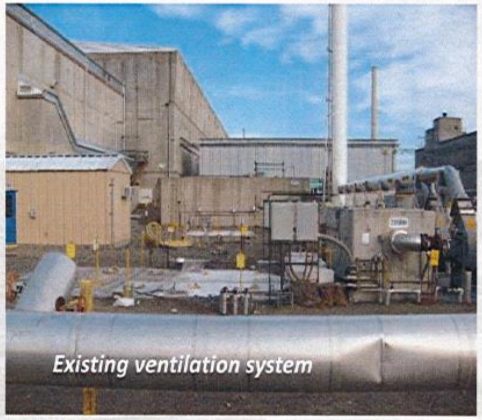


Vessels and pipes in black cell

Waste Encapsulation Storage Facility

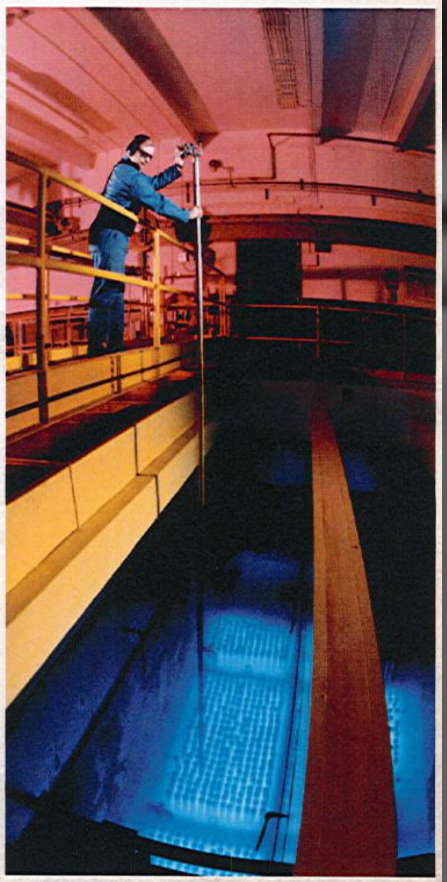
- Built in 1971 to process, encapsulate, and store cesium and strontium from Hanford's single-shell waste tanks
- Processed cesium and strontium from 1974 through 1985
- Currently stores 1,936 cesium/strontium capsules in pools of water

Ventilation and Hot Cell Stabilization Project



Existing ventilation system

Recent crane maintenance



U.S. DEPARTMENT OF ENERGY

Sellafield Trip